

Constraints on Intrinsic UV Absorption in NGC 3783

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Abstract. Results from an analysis of the intrinsic UV absorption in the Seyfert 1 galaxy NGC 3783 are presented. We focus on two new results that demonstrate techniques for deriving important constraints on the physical conditions and geometry of the absorbers. First, using variability in the spectrum, the emission-line profile is separated into distinct kinematic components and the effect on the interpretation of covering factors and column densities is demonstrated. Second, measurements of the $2s2p\ ^3P$ metastable levels of C^{+2} derived from the C III*1175-76 absorption multiplet are presented. New calculations of the metastable level populations are given and shown to provide a powerful diagnostic of the density (and thus location) and temperature in an absorber.

1. Introduction

Recent surveys with high-resolution UV spectra have shown that mass outflow is common in Seyfert 1 galaxies, appearing as blueshifted absorption in more than half of observed objects (Crenshaw et al. 1999). Detailed studies are needed to determine the physical conditions (density, ionization structure, total gas column) and geometry of the absorbers. Here, we focus on constraints derived on the absorbers in the UV spectrum of NGC 3783 to demonstrate some techniques that can be used to probe mass outflow in AGNs.

2. Isolating Emission-Line Components: Effect on Covering Factor

Since the background AGN light that the absorption features are imprinted on is comprised of distinct emission sources with different flux distributions, sizes, and geometries, the most general treatment of absorption features should take into account the different covering factors associated with each source. The Lyman series lines in the averaged STIS and *FUSE* spectra were used to separate the individual covering factors of the continuum and emission line sources in NGC 3783 (Gabel et al. 2003). By incorporating variability of the emission-line profiles, that analysis can be extended to treat *distinct emission-line regions*.

Figure 1 shows the C IV, Ly α , and N V emission-line profiles in both high-state (solid line) and low-state (dotted line) STIS spectra. The low-state profiles have been scaled to match the flux in the high velocity wings of the high-state spectrum. The profiles diverge near line center due to the superposition of a varying broad line region component and a non-varying narrower component (an intermediate line region, ILR). The ILR flux profiles (dashed lines) were solved as described in Gabel et al. (2004, in preparation).

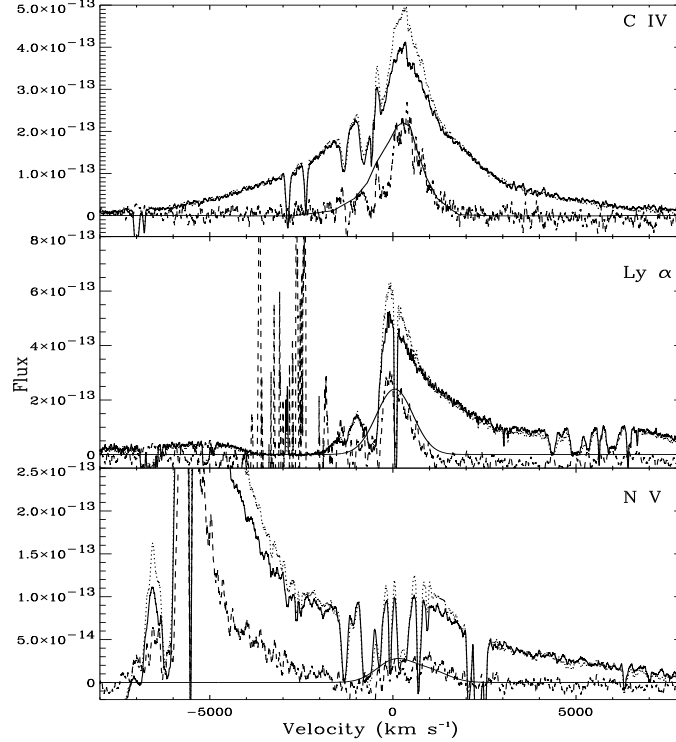


Figure 1. Emission line region profiles of averaged high-state and low-state spectra for C IV, Ly α , and N V. Low state profiles (dotted lines) are scaled to match the high-state fluxes in the high-velocity wings. The dashed lines give the non-varying (ILR) component.

Figure 2 shows the N V absorption profiles for two normalizations to demonstrate the effect of treating the covering factors of distinct emission components separately. In the left panel, the absorption has been normalized simply by dividing the total observed spectrum by our fit to the continuum plus total emission-line flux, i.e., the BLR + ILR. In the right panel, the ILR flux has first been subtracted out of both the data and emission-line fits, which is equivalent to assuming the ILR is completely unocculted by the absorbers. For each normalization, both the high-state (top panel) and low-state (bottom panel) spectra are plotted for comparison and the two doublet lines are overlayed, shifted to coincide in radial velocity. This shows that if the covering factors of the emission components are assumed to be the same, then the N V absorption is not saturated and has effective covering factors in the range $\approx 0.6 - 0.65$ for components 1 – 3. The similarity in the absorption depths between the high and low-states (for both doublet lines) in the left panel implies there is little change

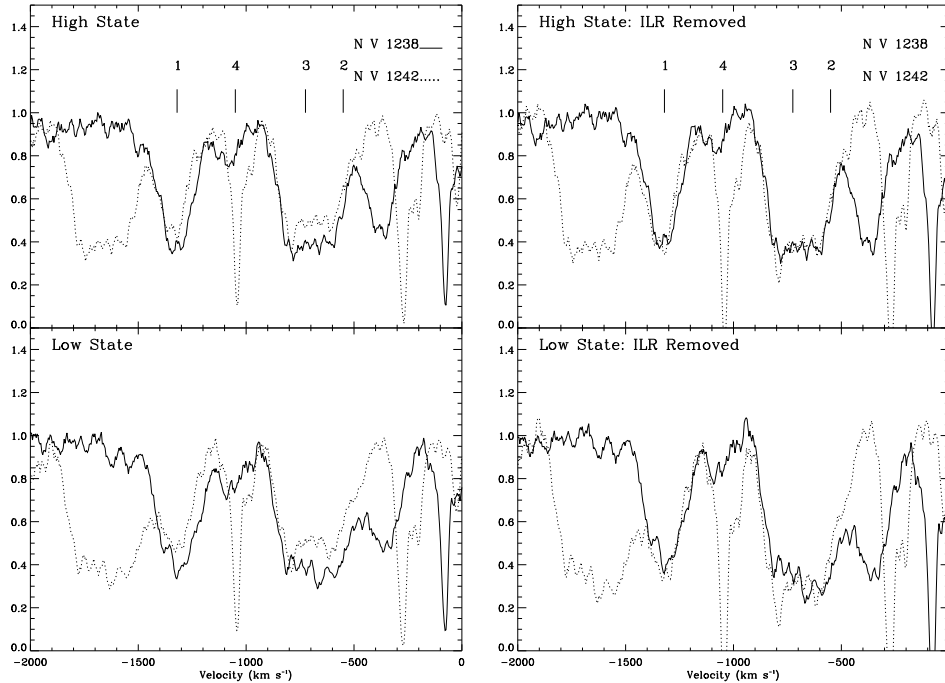


Figure 2. Effect of treating individual covering factors of distinct emission components. N V absorption profiles shown for two normalizations: dividing by fit to total emission (left panel) and first subtracting out the ILR profile (right panel). The high (top) and low (bottom) state spectra are shown for each case, and the N V 1242 line (dotted) is overlaid on the N V 1238 line.

in the column densities for this scenario. Conversely, if the ILR is unocculted, the equivalent absorption depths of the two doublet lines indicates the absorption is saturated in both the low and high states in some of the components. This leads to significant differences in interpreting the physical conditions and variability in the absorption.

3. C III* $\lambda 1175$ Absorption as a Density Diagnostic

The C III* $\lambda\lambda 1175$ multiplet lines have been used as a density diagnostic for AGN absorbers in several studies. However, as pointed out by Behar et al. (2003, ApJ, in press), the high densities derived in these studies (e.g., Gabel et al. 2003) were based on calculations of level populations that only treated the 3P_1 level. The $J=0$ and 2 levels have much lower radiative transition probabilities to the ground state and thus are populated at densities that are lower by several orders of magnitude (Bhatia & Kastner 1993). We have computed the relative populations of the 3P_J levels, extending the results of Bhatia & Kastner (1993) down to electron temperatures expected for the photoionized UV absorbers seen in AGNs. Collisional excitation and de-excitation and radiative decay between the six lowest terms/levels of the C^{+2} ion were included in our calculations. The top panel of Figure 3 shows the C III*1175 absorption

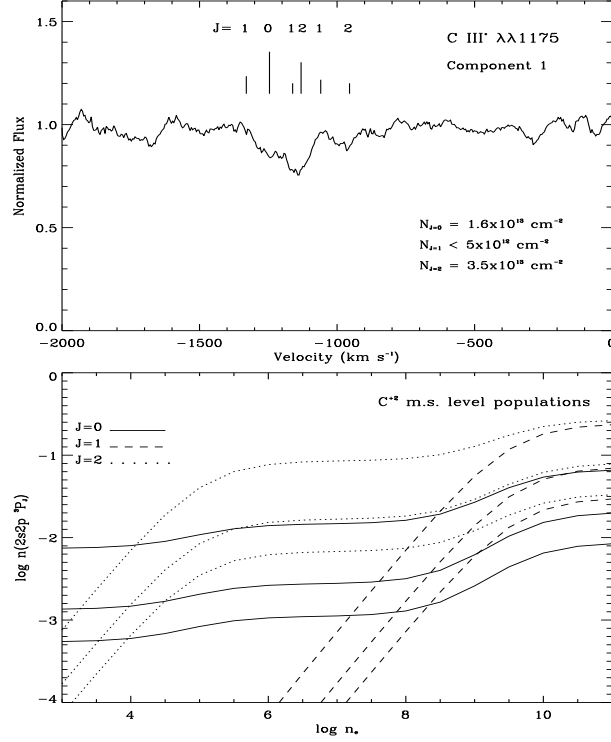


Figure 3. C III*1175 absorption showing the resolved multiplet lines (top panel). Column densities measured for each metastable level are given below the spectrum. Calculation of C²⁺ metastable level populations (bottom panel) as a function of density for $T_e=16000$ (lower), 20000, and 40000(upper) K.

complex in NGC 3783, with the location of the six multiplet lines marked and identified by the J level of the transition. Measured column densities for each metastable level are given below the spectrum. The bottom panel shows the computed populations of the metastable levels over a large range in density for $T_e = 16000$, 20000, and 40000 K (bottom to top). Thus, if the absorption is sufficiently narrow to resolve and measure individual lines in the C III* multiplet, the *ratios* of the excited level populations give a very tight constraint on the electron density. For NGC 3783, the $J=2 : J=0$ column density ratios, $N_{J=2}/N_{J=0} = 2.2$, gives $n_e = 3 \times 10^4 \text{ cm}^{-3}$, which is largely insensitive to temperature. Combining this with a measurement of the ground state population provides a stringent temperature diagnostic. The full implications of this measurement for the absorbers in NGC 3783 will be given in Gabel et al. (2004, in preparation).

References

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